

WHAT IS CLAIMED IS:

1. A first method of depositing a film of a metal chalcogenide, comprising the steps of:

- 5 contacting: at least one metal chalcogenide; a hydrazine compound represented by the formula:



- 10 wherein each of R^1 , R^2 , R^3 and R^4 is independently selected from the group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms; and optionally, an elemental chalcogen selected from the group consisting of: S, Se, Te and a combination thereof; to produce a solution of a hydrazinium-based precursor of said
15 metal chalcogenide;

 applying said solution of said hydrazinium-based precursor of said metal chalcogenide onto a substrate to produce a film of said precursor; and thereafter

- annealing said film of said precursor to remove excess hydrazine
20 and hydrazinium chalcogenide salts to produce a metal chalcogenide film on said substrate.

2. The method of claim 1, wherein said metal chalcogenide comprises a metal selected from the group consisting of: Ge, Sn, Pb, Sb,
25 Bi, Ga, In, Tl and a combination thereof and a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

3. The method of claim 1, wherein said metal chalcogenide is represented by the formula MX or MX_2 wherein M is a metal selected from
30 the group consisting of: Ge, Sn, Pb and a combination thereof; and

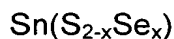
wherein X is a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

4. The method of claim 1, wherein said metal chalcogenide is represented by the formula M_2X_3 wherein M is a metal selected from the group consisting of: Sb, Bi, Ga, In and a combination thereof; and wherein X is a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

5. The method of claim 1, wherein said metal chalcogenide is represented by the formula M_2X wherein M is Tl; and wherein X is a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

6. The method of claim 1, wherein said metal is selected from the group consisting of: Sn and Sb; and wherein said chalcogen is selected from the group consisting of: S and Se.

7. The method of claim 6, wherein said chalcogenide is represented by the formula:



wherein x is from 0 to 2.

8. The method of claim 1, wherein each of R^1 , R^2 , R^3 and R^4 is independently selected from the group consisting of: hydrogen, aryl, methyl and ethyl.

9. The method of claim 1, wherein R^1 , R^2 , R^3 and R^4 are hydrogen.

10. The method of claim 1, wherein said metal chalcogenide film is in the form of a thin film.

5 11. The method of claim 1, wherein said metal chalcogenide film comprises a polycrystalline metal chalcogenide or single crystals of said metal chalcogenide.

10 12. The method of claim 11, wherein said polycrystalline metal chalcogenide has a grain size equal to or greater than the dimensions between contacts in a semiconductor device.

15 13. The method of claim 1, wherein said annealing step is carried out at a temperature and for a length of time sufficient to produce said metal chalcogenide film.

14. The method of claim 1, wherein said substrate is selected from the group consisting of:

20 Kapton, silicon, amorphous hydrogenated silicon, silicon carbide (SiC), silicon dioxide (SiO₂), quartz, sapphire, glass, metal, diamond-like carbon, hydrogenated diamond-like carbon, gallium nitride, gallium arsenide, germanium, silicon-germanium, indium tin oxide, boron carbide, boron nitride, silicon nitride (Si₃N₄), alumina (Al₂O₃), cerium(IV) oxide
25 (CeO₂), tin oxide (SnO₂), zinc titanate (ZnTiO₂), a plastic material and a combination thereof.

15. A film prepared by the method of claim 1.

30 16. A second method of depositing a film of a metal chalcogenide, comprising the steps of:

contacting: at least one metal chalcogenide and a salt of an amine compound with H₂S, H₂Se or H₂Te, wherein said amine compound is represented by the formula:

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wherein each of R⁵, R⁶ and R⁷ is independently selected from the group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms, to produce an ammonium-based precursor of said metal chalcogenide;

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contacting said ammonium-based precursor of said metal chalcogenide, a hydrazine compound represented by the formula:

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wherein each of R¹, R², R³ and R⁴ is independently selected from the group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms, and optionally, an elemental chalcogen selected from the group consisting of: S, Se, Te and a combination thereof; to produce a solution of a hydrazinium-based precursor of said metal chalcogenide in said hydrazine compound;

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applying said solution of said hydrazinium-based precursor of said metal chalcogenide onto a substrate to produce a film of said precursor; and thereafter

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annealing said film of said precursor to remove excess hydrazine and hydrazinium chalcogenide salts to produce a metal chalcogenide film on said substrate.

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17. The method of claim 16, wherein said metal chalcogenide comprises a metal selected from the group consisting of: Ge, Sn, Pb, Sb,

Bi, Ga, In, Tl and a combination thereof and a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

18. The method of claim 16, wherein each of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 and R^7 is independently selected from the group consisting of:
5 hydrogen, aryl, methyl and ethyl.

19. The method of claim 16, wherein R^1 , R^2 , R^3 , R^4 , R^5 , R^6 and R^7 are hydrogens.
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20. The method of claim 16, wherein said metal chalcogenide film is in the form of a thin film.

21. The method of claim 16, wherein said metal chalcogenide
15 film comprises a polycrystalline metal chalcogenide or single crystals of said metal chalcogenide.

22. The method of claim 21, wherein said polycrystalline metal chalcogenide has a grain size equal to or greater than the dimensions
20 between contacts in a semiconductor device.

23. The method of claim 16, wherein said annealing step is carried out at a temperature and for a length of time sufficient to produce said metal chalcogenide film.
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24. The method of claim 16, wherein said substrate is selected from the group consisting of:

Kapton, silicon, amorphous hydrogenated silicon, silicon carbide
30 (SiC), silicon dioxide (SiO₂), quartz, sapphire, glass, metal, diamond-like carbon, hydrogenated diamond-like carbon, gallium nitride, gallium

arsenide, germanium, silicon-germanium, indium tin oxide, boron carbide, boron nitride, silicon nitride (Si₃N₄), alumina (Al₂O₃), cerium(IV) oxide (CeO₂), tin oxide (SnO₂), zinc titanate (ZnTiO₂), a plastic material and a combination thereof.

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25. A film prepared by the method of claim 16.

26. A method of preparing an improved field-effect transistor of the type having a source region and a drain region, a channel layer
10 extending between the source region and the drain region, the channel layer including a semiconducting material, a gate region disposed in spaced adjacency to the channel layer, an electrically insulating layer between the gate region and the source region, drain region and channel layer, wherein the improvement comprises:
15 preparing a channel layer comprising a film of a metal chalcogenide semiconducting material by a first or second method;

wherein said first method comprises the steps of:

contacting: at least one metal chalcogenide; a hydrazine compound
20 represented by the formula:



wherein each of R¹, R², R³ and R⁴ is independently selected from the
25 group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms; and optionally, an elemental chalcogen selected from the group consisting of: S, Se, Te and a combination thereof; to produce a solution of a hydrazinium-based precursor of said metal chalcogenide;

applying said solution of said hydrazinium-based precursor of said metal chalcogenide onto a substrate to produce a film of said precursor; and thereafter

annealing said film of said precursor to remove excess hydrazine
5 and hydrazinium chalcogenide salts to produce a metal chalcogenide film; and

wherein said second method comprises the steps of:

contacting: at least one metal chalcogenide and a salt of an amine
10 compound with H_2S , H_2Se or H_2Te , wherein said amine compound is represented by the formula:



15 wherein each of R^5 , R^6 and R^7 is independently selected from the group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms, to produce an ammonium-based precursor of said metal chalcogenide;

contacting said ammonium-based precursor of said metal
20 chalcogenide, a hydrazine compound represented by the formula:



wherein each of R^1 , R^2 , R^3 and R^4 is independently selected from the
25 group consisting of: hydrogen, aryl, methyl, ethyl and a linear, branched or cyclic alkyl of 3-6 carbon atoms, and optionally, an elemental chalcogen selected from the group consisting of: S, Se, Te and a combination thereof, to produce a solution of a hydrazinium-based precursor of said metal chalcogenide in said hydrazine compound;

applying said solution of said hydrazinium-based precursor of said metal chalcogenide onto a substrate to produce a film of said precursor; and thereafter

annealing said film of said precursor to remove excess hydrazine
5 and hydrazinium chalcogenide salts to produce a metal chalcogenide film on said substrate.

27. The method of claim 26, wherein said source region, channel
layer and drain region are disposed upon a surface of a substrate, said
10 electrically insulating layer is disposed over said channel layer and extending from said source region to said drain region, and said gate region is disposed over said electrically insulating layer.

28. The method of claim 26, wherein said gate region is
15 disposed as a gate layer upon a surface of a substrate, said electrically insulating layer is disposed upon said gate layer, and said source region, channel layer, and drain region are disposed upon said electrically insulating layer.

20 29. The method of claim 26, wherein said metal chalcogenide film is in the form of a thin film.

30. The method of claim 29, wherein said thin film has a
thickness of from about 5 Å to about 2,000 Å.

25 31. The method of claim 26, wherein said metal chalcogenide film comprises a polycrystalline metal chalcogenide or single crystals of said metal chalcogenide.

32. The method of claim 31, wherein said metal chalcogenide film is polycrystalline with a grain size equal to or greater than the dimensions between contacts in a semiconductor device.

5 33. The method of claim 26, wherein said metal chalcogenide comprises a metal selected from the group consisting of: Ge, Sn, Pb, Sb, Bi, Ga, In, Tl and a combination thereof and a chalcogen selected from the group consisting of: S, Se, Te and a combination thereof.

10 34. The method of claim 26, wherein each of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 and R^7 is independently selected from the group consisting of: hydrogen, aryl, methyl and ethyl.

15 35. The method of claim 34, wherein R^1 , R^2 , R^3 , R^4 , R^5 , R^6 and R^7 are hydrogens.

36. The method of claim 26, wherein said annealing step is carried out at a temperature and for a length of time sufficient to produce said metal chalcogenide film.

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37. The method of claim 36, wherein said temperature is from about 25 °C to about 500 °C.

25 38. The method of claim 37, wherein said temperature is from about 250 °C to about 350 °C.

39. The method of claim 26, wherein said substrate is selected from the group consisting of:

30 Kapton, silicon, amorphous hydrogenated silicon, silicon carbide (SiC), silicon dioxide (SiO₂), quartz, sapphire, glass, metal, diamond-like

carbon, hydrogenated diamond-like carbon, gallium nitride, gallium
arsenide, germanium, silicon-germanium, indium tin oxide, boron carbide,
boron nitride, silicon nitride (Si_3N_4), alumina (Al_2O_3), cerium(IV) oxide
(CeO_2), tin oxide (SnO_2), zinc titanate (ZnTiO_2), a plastic material and a
5 combination thereof.

40. An improved field-effect transistor prepared by the method of
claim 26.